Structure of hydrogen atom

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Rutherford's concept of continually moving electrons around the nucleus and the experimentally verified matter-wave theory proposed by de Broglie made the pathway to the development of the currently accepted Atomic Orbital Model of atom. However since there is no evidence for the electron's continuous motion around the nucleus, and the fact that the matter-wave experiments were performed by artificially accelerated electrons, it may not be reasonable to think that the electrons in an atom act as matter-wave, the behaviour which the electrons demonstrated in the matter-wave experiment. In short, there are more studies still needed to understand the structure of atom. Here I discuss an experiment which involves the interaction of light with hydrogen gas, led to assume that, contrary to the present-day belief, the electrons or nuclei of atoms that in a medium have no role in the transmission of light through that medium and besides electrons and nucleus, an atom comprises of another state of matter which acts as a transmission medium for light and slows down the light's speed (reason for the refraction of light). This leads to consider about an alternative model for atom which is more consistent with the experimental result. This communication proposes a new atom model for hydrogen, which can provide a new insight into how a hydrogen atom creates its spectral lines, how the splitting of spectral lines occurs etc.

The Planetary model of atom[1] proposed by Rutherford followed by the gold foil experiment[2] failed to explain the stability of atom and why atoms of each element emit and absorb unique spectral lines. Subsequently, Niels Bohr proposed the Bohr model[3] , which consists of the idea that electrons in an atom can move around the nucleus only in allowed orbits called "Stationary orbits". According to this model, when we consider a hydrogen atom, it has an orbit, which is closest to the nucleus with the lowest energy level called the ground state n1, the next orbit n2, followed by the next orbit n3 and so on. Each orbit has a different energy level. Electron emits or absorbs a photon because of the transition of the electron between the allowed orbits. According to this model the energy of an emitted or absorbed photon $E = Ef – Ei$, where f and i represent final and initial orbit.

However, although this model seemed to be helpful in explaining the spectral lines of hydrogen atom (HA), it failed to explain fine structure[4], splitting of spectral lines[5], spectral lines of multi-electron atoms etc. At that time inspired by Einstein who explained photo electric effect[6] by considering light as particle - which was previously thought of a kind of wave- de Broglie proposed the matter-wave theory[7] which suggested that moving electrons exhibit a wave-like behaviour besides its particle nature. According to this theory the wavelength of a moving electron $\lambda = h/p$, where h is Plank constant and p is the momentum of electron. By passing accelerated electrons through Nickel Crystal, Davisson and Germer had observed the electron's wave-like behaviour[8], and experimentally verified the de Broglie's theory. G.P Thompson's experiment[9] had also obtained the same result. Based on these results Heisenberg proposed Uncertainty principle[10] and Schrödinger proposed Wave function equation[11] which led to the development of the currently accepted model of atom called Atomic Orbital Model[12] or Wave Mechanical Model. According to this model, the electrons in an atom are situated in inner and outer orbitals, which have different energy levels around the nucleus as electron cloud or matter-wave.

Although Rutherford's planetary model of atom was subsequently rejected, the scientific community had accepted his idea of continually moving electrons around the nucleus. However, although the gold foil experiment performed under the supervision of Rutherford explicitly proved that atom has nucleus, the experiment did not provide any information about the "status" of electrons in atoms. At the same time, the de Broglie's matter-wave theory had verified using artificially accelerated electrons. However, since there is no evidence for the electron's continuous motion around the nucleus, we cannot consider that the electrons in an

atom act as matter-wave, the behaviour which the electrons demonstrated in the matter-wave experiment. In short, there are more studies still needed to be done about the structure of atom.

There are similarities that can be observed among an electrical resonator (ER) circuit and an atom of an element. An ER circuit absorbs and emits radio waves only which match with the resonant frequency of that circuit. Similarly, at low-temperature and low-pressure atoms of an element absorb photons from a continuous spectrum (CS) of light, with only the wavelengths which include in the line spectrum of that element and emits photons in the same wavelengths. From this, we can understand that, like the free electrons in an ER Circuit, the electrons in an atom are also situated in some kinds of resonant columns. At the same time, as a divergence from an ER circuit, because an atom of an element absorbs and emits a large number of different wavelength photons, we can understand that, an atom consists of a large number of resonant columns in it. An ER circuit emits radio wave because of the vibration of electrons in that circuit. Therefore, we can conclude that an atom emits photons also because of the vibration of electrons in that atom.

According to the present-day belief, the electrons in the atoms of a transparent medium is mostly responsible for the transmission of light through that medium[13]. It describes that, the vibrating electric fields and magnetic fields of incident photons make the electrons in the atoms of the medium to vibrate with the frequencies of the incident photons and which cause the electrons to re-create photons in the same frequencies. Light is transmitted through the medium as the sum of the photons, which are re-created in the above stated way, along with the original photons. It is also believed that, the fact that the speed of light is slightly reduced in a medium, is caused by this kind of interaction between the photons and the electrons.

Here we will see the interaction between photons and hydrogen gas (HG). When a CS of light incidents normal (90^o angle) on HG (HG is brought in a transparent container), which is at low-temperature and low-pressure, only photons which comprises in the line spectrum of hydrogen is absorbed and rest of the photons will pass in a straight line through the HG, at a speed slightly less than the speed of light (c) [see Fig.1(a)]. [The speed of light with a wavelength of 589.3 nm in HG, at a pressure of 101325 Pa and temperature of 0 °C, $v = {}^{c}/_{n} = \frac{2.99792458\text{x}10^8}{1.000132}$ m/s = $2.99752890\text{x}10^8$ m/s, where n is the refractive index of hydrogen[14] and c is the speed of light in vacuum]. The photons with the wavelength of the absorbed photons are emitted at different directions. As the photons with the wavelengths which comprised in the line spectrum of hydrogen incident on the HG, the electron in each of the HAs vibrate in free orientations. This is the reason why HG emits photons in the above stated manner [Fig.1(c)]. However, it may not be reasonable to think that, the electrons in the HAs which vibrate in free orientations and emit photons in different directions when they interact with one group of photons, could vibrate in such a way that their vibrations could guide another group of photons through the HG in a straight line when the electrons interact with them. In short, the electrons in the HAs can only produce hydrogen's emission lines, but they cannot behave differently to two different groups of photons.

If the CS of light incidents on high-pressure HG, then more different wavelength photons will be absorbed and thus the number of different wavelength photons which pass straight through the HG will be reduced [Fig.1(b)]. This indicate that, as pressure increases, more different wavelength photons are interacted with the electrons in the HAs and the only photons which are not interacted with the electrons are passed straight through the HG [see Transmitted beam-2 in fig.1(b)]. This also point out to the fact that the electrons in the HAs have no role in the transmission of light through the HG. At the same time, it is also not reasonable to think that, the nuclei of atoms of a medium, which are more massive and require more kinetic energy to vibrate, help the transmission of light through that medium. These facts indicate the presence of another state of matter in atoms which acts as a transmission medium for light and influences the light's speed.

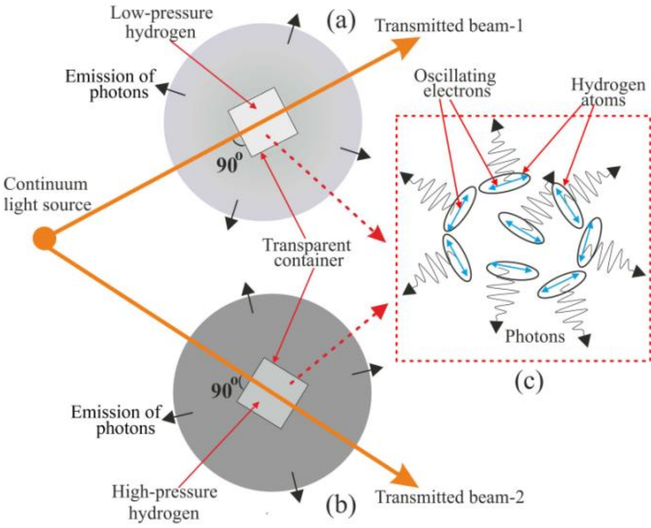

FIG.1. (a) At low-temperature and low-pressure hydrogen gas (HG) absorbs and emits only photons which comprises in the line spectrum of hydrogen. The transmitted beam-1 consists of all wavelength photons, which are not included in the line spectrum of hydrogen. (b) High-pressure HG absorbs and emits photons with more different wavelengths. The transmitted beam-2 consists of a less number of different wavelength photons. (the transmitted beam-1 and transmitted beam-2, both are incident normal to the surfaces of the transparent HG containers and pass straight through the HGs). (c) HG emits photons in different directions.

This matter plays the following roles in the structure of a HA. 1) Gives volume: - The Charge radius of the nucleus (proton) of a HA only (R_p) = 0.8775(51)x10-^{15}m[15,16]. However the value of the Bohr radius (a0) = 5.2917721092(17)x10^{-11}m[15,16] (but the actual radius of a HA is greater than this value). 2) Prevents the electron from falling into the nucleus: - Although there is an attractive force of 8.22 x 10^{-8}N between the nucleus and the electron, the electron is not collapsing into the nucleus. [$Fe = k\,\frac{q_e q_p}{\mathrm{r}^2}$ = $(8.99\text{x}10^9\ \mathrm{N.m^2/C^2})\,\frac{(1.60\text{x}10^{-19}\ \mathrm{C})(1.60\text{x}10^{-19}\ \mathrm{C})}{(5.29\text{x}10^{-11}\mathrm{m})^2}$ = 8.22x10^{-8}N, where Fe is the magnitude of electric force, k is electrostatic constant, q_e and q_p are the charges of electron and proton[15,16] respectively and r is Bohr radius]. 3) Creates resonant columns (we saw that the electrons in an atom are situated in some kind of resonant columns). Because the space inside an atom is filled with this matter, we can call this matter as space matter (SM).

Electron collision experiments can provide many important informations about the structure of an atom. While the collision of low-energy electrons on a multi-electron atom causes the emission of only long-wavelength (low-energy) photons, a collision of high-energy electrons on the same atom results the emission of short-wavelength (high-energy) photons. For example, as the collision-energy of electrons in an X-ray tube increases, the wavelength of photons that are emitted by the target of the X-ray tube decreases. At the same time, if the colliding electrons have the sufficient energy, an atom emits the shortest wavelength photons which that atom can emit. We know that inner electrons emit short wavelength photons. While low-energy electrons are only able to excite outer electrons of an atom, high-energy electrons penetrate outer regions of an atom and excite inner electrons. This indicates that the SM density is less in the outer regions of an atom and it increases with the decreasing of the distance from the nucleus. We can assume that, this difference in the densities of the SM is the reason for the low-frequency resonant frequency for outer regions and high-frequency resonant frequency for inner regions of an atom. The fact is that at high-temperature and high-pressure, atoms of an element produce large number of spectral lines compared with their elemental spectral lines, indicates that an atom consists of a large number of resonant columns in it. Because these resonant columns, large in number act as thin layers, we can consider a resonant column as a thin shell.

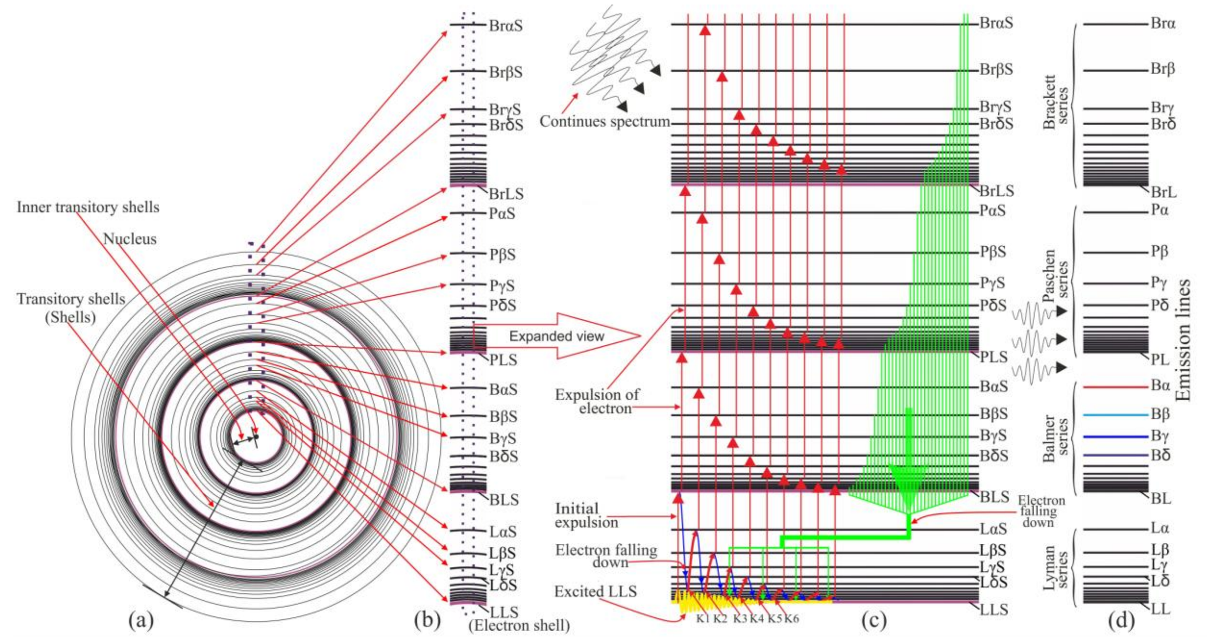

FIG.2 (a) Cross sectional diagram of hydrogen atom [illustrates Lyman shell series to Brackett shell series]. As the distance increases from the nucleus, the density of space matter (SM) decreases. (b) Enlarged view of the highlighted portion of the diagram (a). (c). Expanded view of the highlighted portion of the diagram (b); it illustrates the expulsion of the electron from inner regions to outer regions and the fall back of the electron from outer regions to the Lyman limit shell (LLS). (d). Formation of the line spectrum of hydrogen atom.

An atom consists of three types of shells. 1) Electron shells (ES): These are the regions in which the electrons are situated in an atom when the atom is in non-excited state. A HA has only one ES [see Fig.2(a) and Fig.2(b)]. Since buoyant force exerted by the ES and the force of attraction between the nucleus and the electron are equal, the electron in a non-excited HA is situated in its ES. In effect, the electron of a HA cannot go beyond the ES and reach any closer to the nucleus. 2) Transitory shells (TSs) -simply "shells": When an electron in an ES is excited, because the density of SM is more in inner regions, the electron will be expelled to an outer low-density SM region. These regions to which the electrons are expelled are TSs. We know that, although HA has only one electron, a HA can emit and absorb photons of different wavelengths. Rest of the photons other than the shortest wavelength photons that were emitted by a HA are emitted from its TSs. 3) Inner transitory shells (ITS): These are the shells that are situated in the inner regions of the innermost ES [TSs and ITSs of hydrogen atom are shown in Fig.2(a)].

Here we will see how a HA creates its absorption spectrum and emission spectrum from a CS of light. The electron of a HA that is in low-temperature and low-pressure HG is situated in the ES [see Fig.2(a) and Fig.2(b)]. Since the shortest wavelength photon that can be emitted by a HA is Lyman limit (LL) photon, we can understand that, the frequency of the LL photon is the resonant frequency of the ES of a hydrogen atom. Here, because the LL photon is emitted from the ES of the HA, we can call this ES as Lyman limit shell (LLS). If a photon from the CS, with the wavelength of a LL photon, interacts with the electron of a non-excited HA, the electron will absorb that photon and the LLS will get excited [see excited LLS (yellow color) in Fig.2(c)]. As a result, the electron will emit a new LL photon [see LL in Fig.2(d)] and will be expelled to an outer region [see Initial expulsion (IE) of electron Fig.2(c)]. However, because of the attraction from the nucleus, when the expelled electron reaches in the Balmer limit shell (BLS) [i.e., the shell from which the Balmer limit (BL) photon is being emitted], the speed of the electron will be reduced to zero, and the electron starts to return to the LLS. This brief halt of the electron creates an opportunity to interact with a BL photon that in the CS and that photon will be absorbed and the BLS will get excited. As a result, the electron will emit a new BL photon [see BL in Fig.2(d)] and will be expelled to Paschen limit shell (PLS) [see PLS in Fig.2(c)]. This process will be continued to the outer shell serieses of the Paschen shell series. In this way, if the electron which is situated either in the LLS or is expelled from an inner shell to an outer shell is excited by interacting with an appropriate wavelength photon, a new photon will be emitted with the wavelength of the interacting photon and the electron will be expelled to the excited shell's corresponding shell in the next outer series.

However, if the electron which is expelled from an inner shell to an outer shell is not being excited again, because of the attraction from the nucleus, it goes back to the LLS. If the electron which is expelled to the BLS goes back to the LLS in this way [see the falling down of electron Fig.2(c)], because of the interval between the expulsion from the LLS and the fall back to the LLS is minimum, as the amplitude of the damping oscillation of the LLS is still high enough, the electron will be kicked [see K1 in Fig.2(c)] to the Lyman alpha shell (LαS). If this electron, which is kicked to the LαS, interacts with a photon that in the CS, with the wavelength of a Lyman alpha (Lα) photon, it will emit a new Lα photon [see Lα in Fig.2(d)] and will be expelled to the Balmer alpha shell (BαS) [see BαS in Fig.2(c)]. Moreover, if the electron which is expelled to the BαS, interacts with a photon that in the CS with the wavelength of a Balmer alpha (Bα) photon, it will emit a new Bα photon [see Bα in Fig.2(d)] and will be expelled to the Paschen alpha shell (PαS) [see PαS in Fig.2(c)].

However, if the electron which is kicked to the LαS [see K1 in Fig.2(c)] is not being excited, it will again fall back to the LLS, and as the result of the oscillation of the LLS with the slightly-reduced amplitude (because of the damping), the electron will be kicked to the Lyman beta shell (LβS) [see K2 in Fig.2(c)]. If the electron which is kicked to the LβS is excited, it will emit a new Lyman beta (Lβ) photon [see Lβ in Fig.2(d)] and will be expelled to the Balmer beta shell (BβS). At the same time, because the amplitude of oscillation of the LLS is being decreased with time, as the interval increases between the expulsion (or kick) of the electron from the LLS and the falls back to the LLS, the electron will be kicked only to an outer shell which is closer to the LLS. In this way, the excitation of the shells closer to the LLS [see Lyman gamma shell (LγS), Lyman delta shell (LδS) etc. and the Continuous Spectrum Shells (CSSs) in Fig.2(c)] to which the electron is kicked [see K3, K4 etc. in Fig.2(c)], causes the emission of Lyman gamma (Lγ) photon, Lyman delta (Lδ) photon etc and also the emission of the CS in the Lyman series [(see Fig.(2)d]. At the same time, as the result of these kinds of excitations, the electron will be expelled to the Balmer gamma shell (BγS), Balmer delta shell (BδS) and also to the shells very close to the Balmer limit shell (BLS) from which the CS in the Balmer series are being emitted [see Fig.2(c)]. However, if the expelled (or kicked) electron from the LLS takes more time to fall back to the LLS, as the LLS loose its excitation with time, the electron will not get any more kicks from the LLS. This tends the electron to interact with a photon that is in the CS with the wavelength of a LL photon, and causes the excitation of the LLS and the emission of a new LL photon [see LL in Fig.2(d)], and followed by the expulsion of the electron to the BLS [see BLS in Fig.2(c)].

Because every HAs (protium) has the same shell structure, at a definite distance from the nucleus, the SM density for every HAs will also be the same. Therefore the electrons which are expelled from a specific inner shell of all HAs will reach on the outer shells having the same resonant frequency, and also when these shells get excited, the electrons emit the same wavelength photons. In short, atoms with the same shell structure have the same number of electrons, create identical spectral lines. At the same time, the difference in the number of neutrons of isotopes of an element creates slight variations in their shell structures. This difference makes slight variations in their spectral lines.

If an electron in an atom is being excited and expelled (or kicked) from a shell at the time when the atom is situated in an external electric field or magnetic field, because of the influence of that field, the electron will be expelled to a different shell, instead of the shell to which the electron gets expelled normally. When a number of atoms of an element are situated in a field, because the field influences not all atoms uniformly, when the electrons in such atoms are expelled, they will be expelled to shells, which have slightly different resonant frequencies. In this way, the electrons of a number of atoms of an element, which are expelled (or kicked) from shells having same resonant frequency, but they are expelled to shells which have slightly different resonant frequencies- they produce slightly different spectral lines- when the shells get excited. This creates the phenomena like Zeeman splitting and stark splitting. The magnitude of this kind of splitting is proportional to the field intensity. I.e., in the presence of a stronger field, the electrons in the atoms are expelled to shells, which have more differences in their resonant frequencies, and when these shells get excited, they produce spectral lines with more differences in their wavelengths. At the same time, the weak electric fields and magnetic fields produced by electrons and nuclei of atoms cause slight splitting in the spectral lines of neighbouring atoms. These kinds of splitting, which can be only observed through high-magnification, are fine structure and hyperfine structure.

Accurate, in-depth knowledge about the structure of atom enhances our capability of manipulating matter at atomic level and leads to accelerated progresses in different technology fields. Certainly, there are more studies needed to be conducted to get answers for the questions like how the shells of an atom are formed? How is chemical energy released? What is the atomic level explanation for magnetism? etc. However, the knowledge is that, besides electrons and the nucleus, an atom comprises of another state of matter, and this matter plays a key role in the structure of atom, which enables us to predict the behaviour of atoms more precisely, and cuts short the path to the advancement of nano-level technologies, thermonuclear fusion technologies and other emerging technologies in applied science. Moreover, the knowledge about a new state of matter and the fact is that light-speed is altered when light is passed through this matter, helps us to make a deeper understanding about light-matter interactions and ultimately about the cosmos itself.

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